Characterization of Arsenic in Refractory Gold Ores Roasting-Cyanidation Processing

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PT Newmont Minahasa Raya, Indonesia operates a refractory gold-ore treatment plant. The deposit is predominately refractory in nature. Extensive studies were performed to develop a process for gold recovery as well as detoxification. The plant operation incorporates whole ore roasting followed by conventional cyanidation and carbon adsorption. The tailings are treated to remove arsenic and other deleterious elements before disposal by submarine tailings placement on the sea floor.

Development of the process for Minahasa was based on a detailed understanding of the ore characteristics. The gold is finely disseminated and associated with fine-grained pyrite enriched in arsenic. A significant fraction of this As-rich sulfide is fine-grained pyrite and is intimately intergrown with gangue minerals. Two different refractory ore types in the deposit were characterized: siliceous pyritic and carbonate pyritic. Blending of siliceous and carbonate ores as roaster feed gave two advantages: (1) the sulfur dioxide generated from roasting of the sulfides was captured by the decomposition products of carbonate minerals, especially dolomite, and (2) the fixation of arsenic in calcine during roasting.

In the roasting reaction, arsenic-bearing pyrite was oxidized to SO_2 and As_2O_5. With decomposition of dolomite, arsenic was fixed as magnesium (or calcium) arsenate in the calcine. Concentrations of arsenic in the gas stream directly after roasting measured from 1 to 10 mg/Nm^3, (equated as 0.03 to 0.3 % of the feed arsenic). The roaster off-gas was treated in a wet scrubber and over 99.9 % of the arsenic was removed. The concentration of arsenic in the scrubber outlet gas stream was below detection limit. The soluble arsenic concentration in the calcine varied depending on the ore minerals and roaster temperature. Plant monitoring indicated the soluble arsenic in the roaster products decreased with increasing roaster temperature. Extensive studies in the laboratory and plant trials were performed to understand the chemistry and optimize the operation system for both gold recovery and arsenic fixation.

In the detoxification circuit, the low concentration of soluble arsenic was precipitated with ferrous sulfate. Ferrous sulfate is not the normal reagent of choice for precipitation of arsenic; ferric salt is more often used. However, the process being operated is in alkaline slurry. With due regard for the upstream effect of plant operations on the arsenic chemistry, the success of this treatment method can be explained by reference to well documented principles of precipitation of arsenic (V) compounds. Based on thermodynamic considerations and test results, a minimum solubility for ferrous arsenic at pH ~8 has been reported. In consideration of an operating plant, ferrous sulfate has two distinct advantages over ferric salts. Ferrous is cheaper on an available iron basis and is easier to handle as it is less corrosive and toxic.

Tailings after detoxification are de-aerated and discharged on the sea floor below the natural ocean thermocline. The long-term stability of metal ions is a concern, especially arsenic in seawater. Extensive large-scale static leach tests on tailings in seawater have been studied. The static leach tests closely simulated the fluid dynamics of submarine disposal, and provided an indication of the long-term stability of the tailings deposited on the ocean floor. Since the plant startup, monitoring work, using sea floor coring methods, measurement of chemistry and turbidity in the water column and measurement of heavy metals uptake in the predominate fish species, has confirmed that the submarine tailing placement system is successful. No measurable changes in the seawater quality have been detected.

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Minahasa Refractory Gold Ores

Invisible gold, size < 0.1 micron

Unable to detect by SEM

- ***Colloidal gold***
- ***Solid solution gold***
- ***Finely disseminated with fine-grained pyrite enriched in arsenic***
- ***Two ore types--Siliceous sulfidic and carbonate sulfidic ores***

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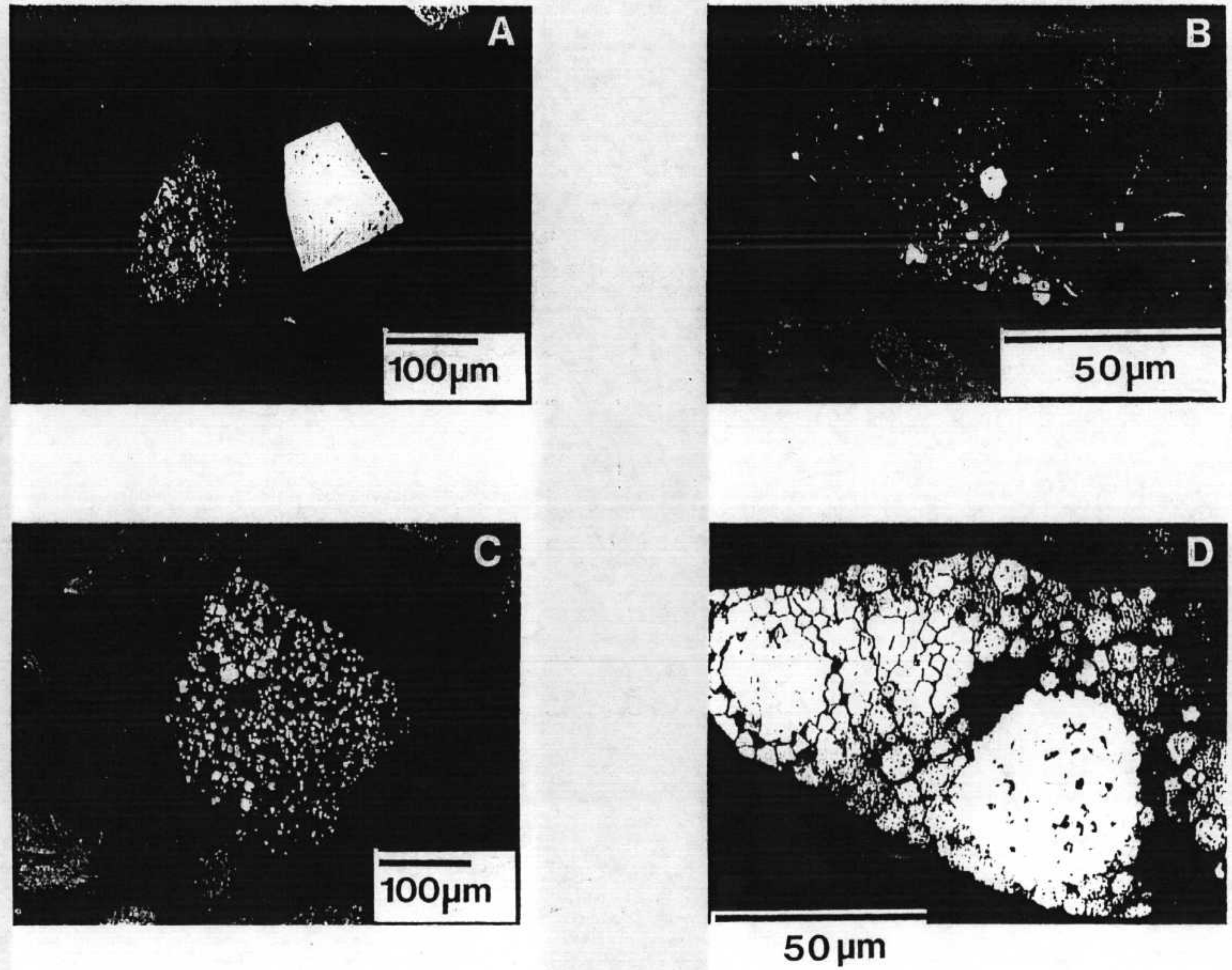
A
100μm
B
50μm
C
100μm
D
50μm

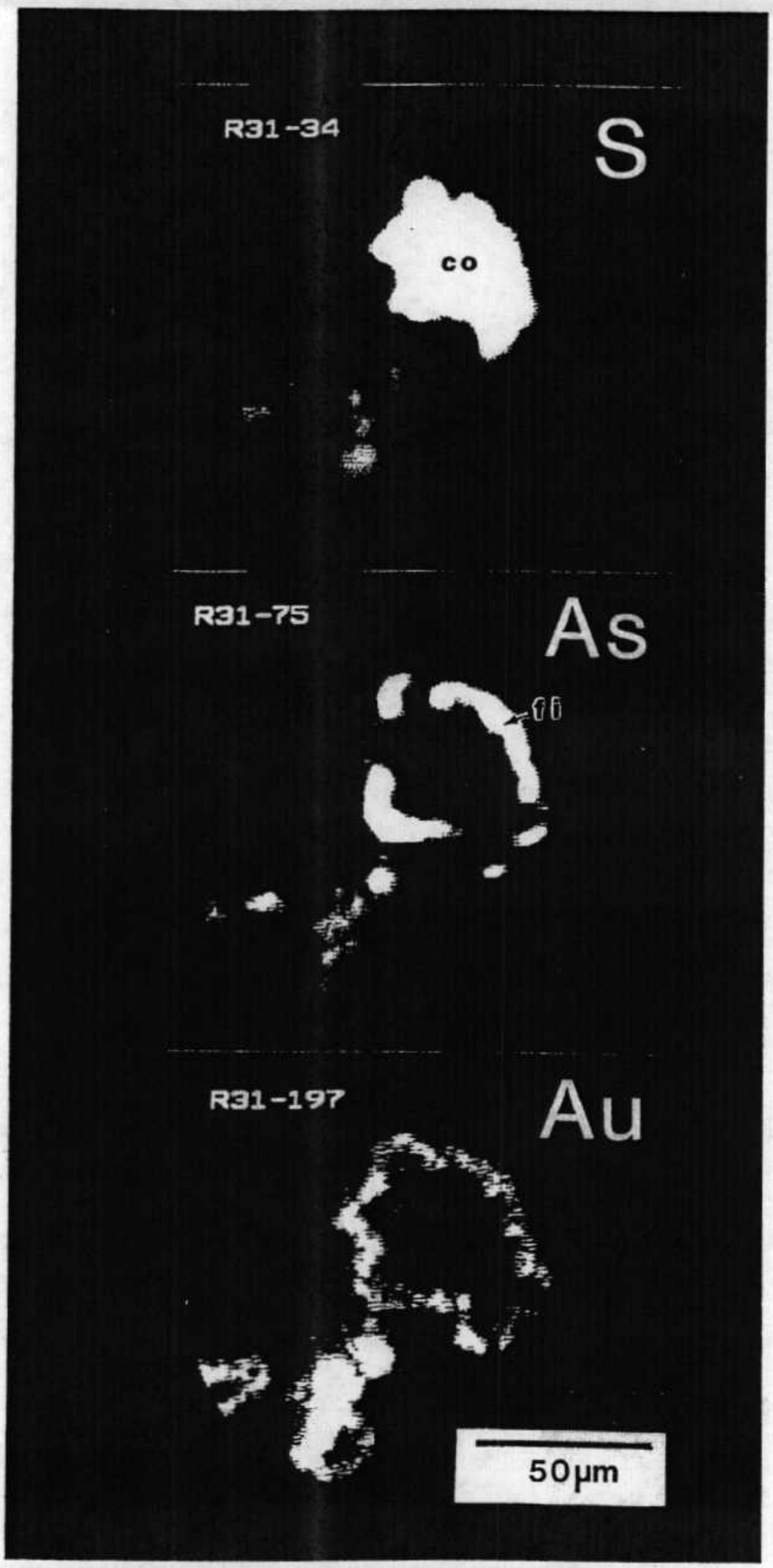

PLATE A1 Au- & As-rich fine-grained pyrite rim

Whole Ore Roasting Process for PT Minahasa Raya

- ***90% gold recovery.***
- ***Blending siliceous and carbonate refractory ores- SO_2 is captured by decomposition of carbonate minerals.***
- ***No acid plant is required.***
- ***Arsenic is fixed in calcine.***
- ***Low capital cost and operation cost.***

PT Newmont Minahasa Raya

- ***Whole Ore Roasting***
- ***Cyanide Leach and Carbon Adsorption***
- ***Tailing Detoxification***
- ***Submarine Tailing Disposal***

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Roasting Reaction

Roasting of Sulfide Minerals:

$2FeAsS + 6\ O_2 = Fe_2O_3 + As_2O_5 + 2\ SO_2$

$2FeS_2 + 5.5\ O_2 = Fe_2O_3 + 4\ SO_2$

Decomposition of Dolomite:

$CaCO_3{\bullet}MgCO_3 = CaCO_3 + MgO + CO_2$

Fixation of Sulfur Dioxide:

$2\ MgO + 2\ SO_2 + O_2 = 2\ MgSO_4$

Fixation of Arsenic:

$3\ MgO + As_2O_5 = Mg_3(AsO_4)_2$

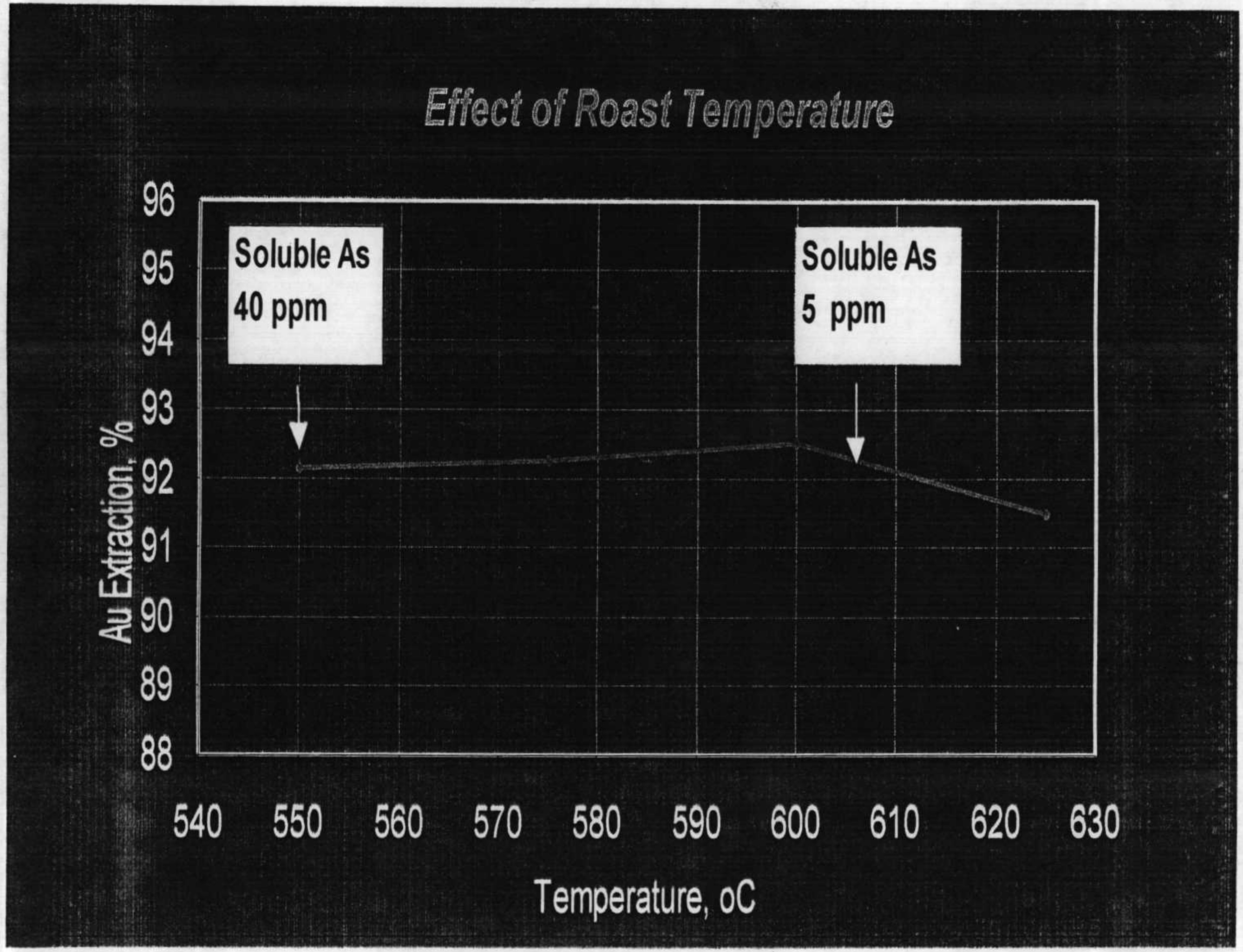
$Fe_2O_3 + As_2O_5 = 2\ FeAsO_4$

Arsenic Behavior in Roasting Process

- *Roaster feed:*
  Arsenic concentration--- 1500-2500 ppm

- *Roaster off-gas before scrubber:*
  Arsenic concentration--- 1 mg/NM^3 (normal)
  10 mg/NM^3 (max)

- *Roaster off-gas after scrubber:*
  Arsenic concentration—0.001 mg/NM^3


Effect of Roast Temperature
Soluble As
40 ppm
Soluble As
5 ppm
Au Extraction, %
96
95
94
93
92
91
90
89
88
540
550
560
570
580
590
600
610
620
630
Temperature, oC

PT Minahasa Raya Wet Plant

Quench → Thickener

↓

Leach Circuit

↓

Detoxification Circuit

(CN, As, Hg)

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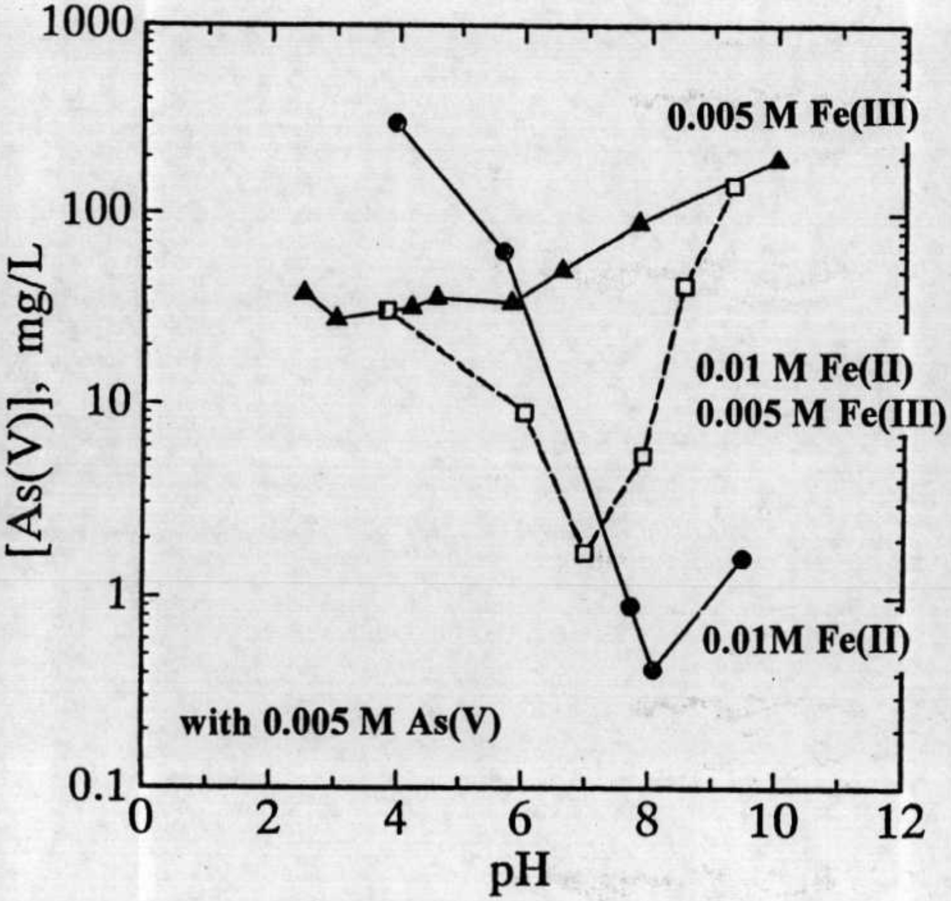
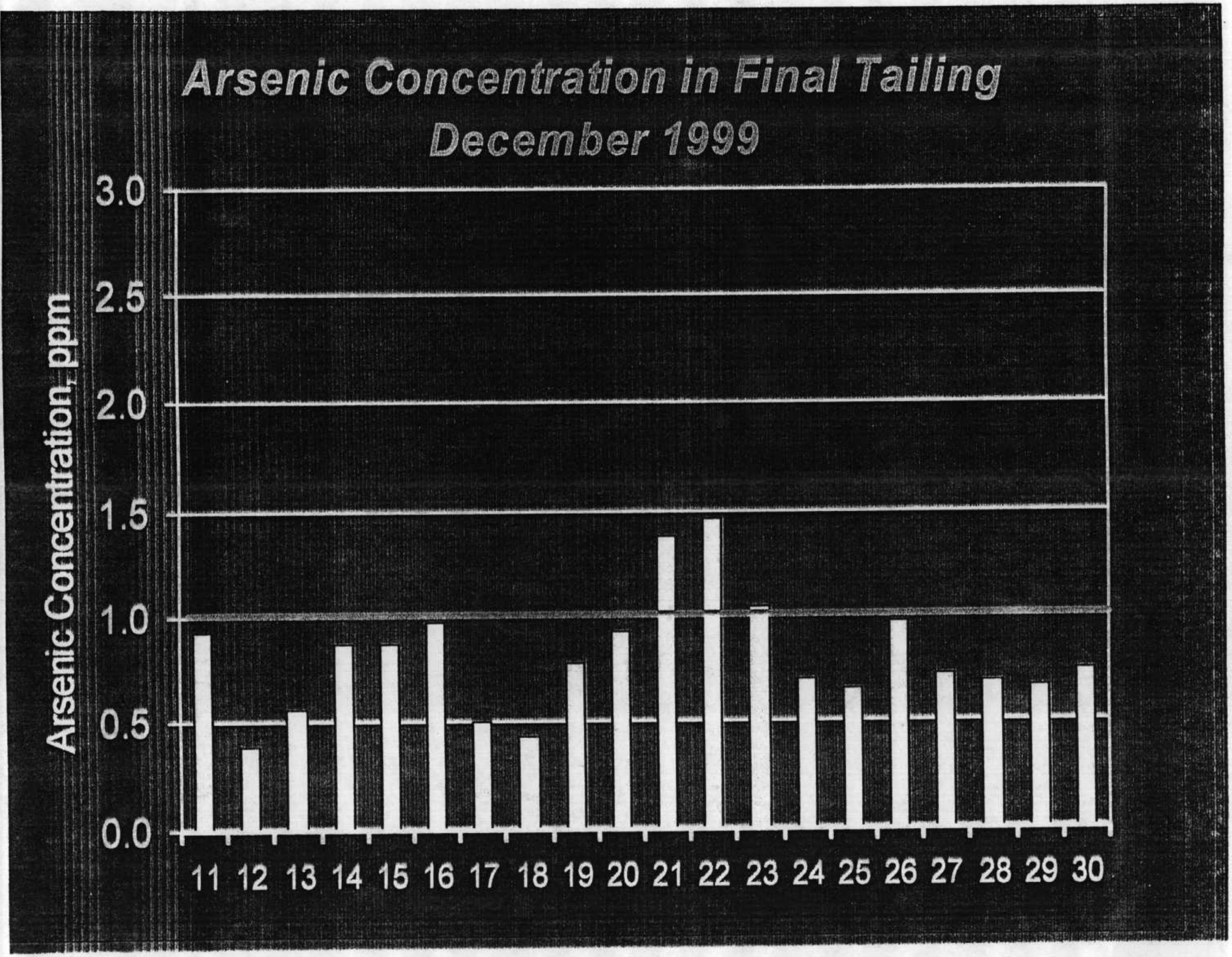
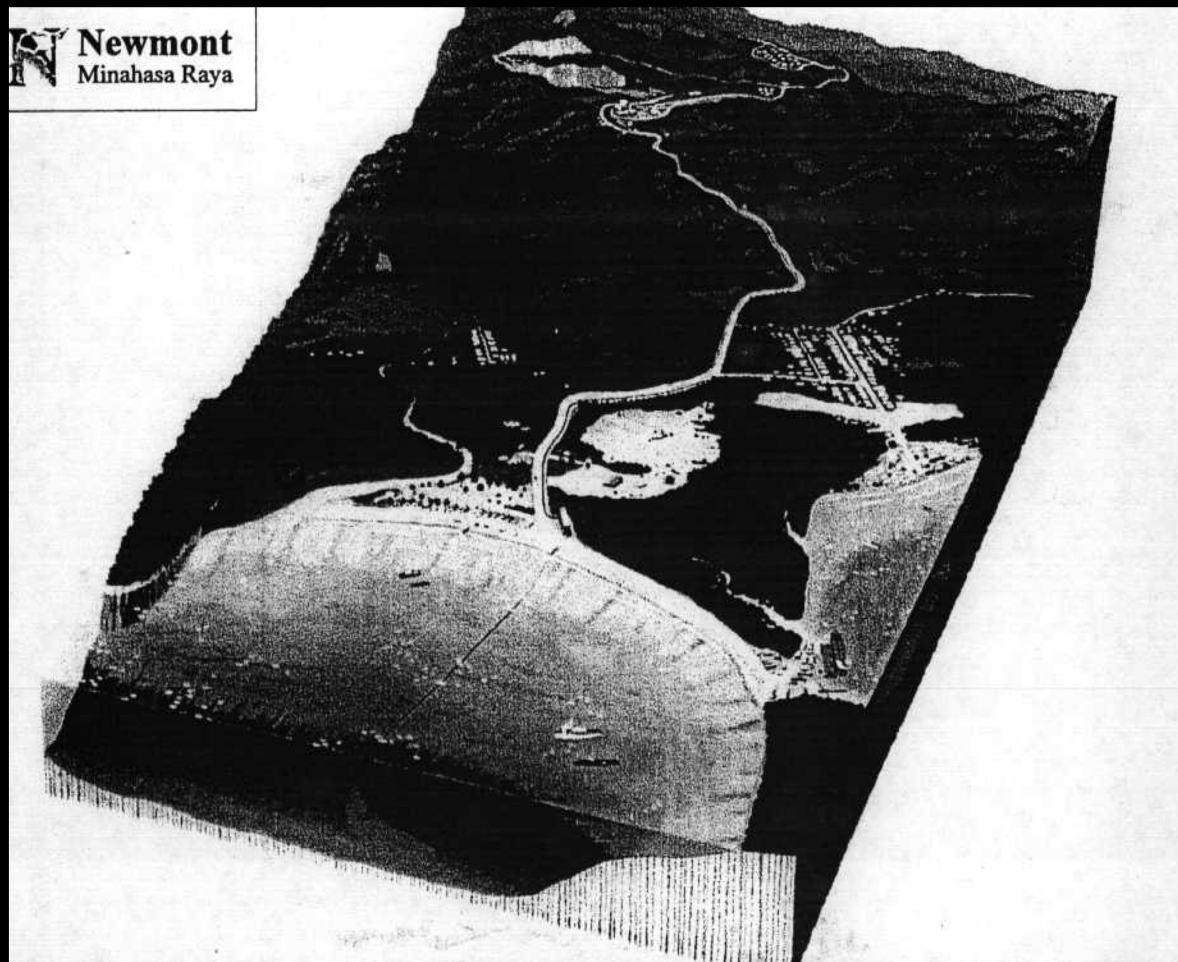
Leach Slurry Detoxification and Tailing Submarine Disposal

- ***Cyanide detoxification using SO_2/air technology.***
- ***Arsenic precipitated as ferroarsenate.***
- ***Mercury precipitated as mercury sulfide.***
- ***Submarine tailing disposal.***


1000
100
10
1
0.1
0
2
4
6
8
10
12
pH
[As(V)], mg/L
0.005 M Fe(III)
0.01 M Fe(II)
0.005 M Fe(III)
0.01M Fe(II)
with 0.005 M As(V)


Arsenic Concentration in Final Tailing
December 1999
Arsenic Concentration, ppm
3.0
2.5
2.0
1.5
1.0
0.5
0.0
11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30


Newmont
Minahasa Raya

PT Newmont Minahasa Raya

- *Gold is finely disseminated and associated with fine-grained pyrite and enriched in arsenic.*
- *Gold recovery is accomplished by whole ore roasting followed by cyanidation and carbon adsorption.*
- *Despite the low arsenic concentration in the ore, the arsenic content has a major impact on gold recovery.*
- *Maximum efficiencies on gold recovery and downstream detoxification have been achieved by monitoring and controlling the processing.*